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Radioisotope Thermionic Power Supply for Spacecraft

The preliminary design of a radioisotope thermionic power supply for unmanned electric propulsion missions to the outer planets utilizes a store of curium-244 in a compact array of capsules as an energy source. Heat evolved by curium disintegration flows to thermionic converters, where part of it is recovered as electrical energy, and the balance is rejected into space. The converters are connected in series-parallel to yield 5 kW of electric power at 15 volts DC.

Protection from radioactivity is provided for personnel and adjacent hardware while the vehicle is on the launch pad or while it is in launch by an envelope shield that contains special safety devices and a heat rejection system. For example, while the power supply is on the ground, the envelope provides a lithium hydride neutron shield and cooling by a flow of water. During launch, heat pipes cool the reactor by providing thermal conduction paths to the outer skin of the envelope. Should a launch abort be necessary, the shield will prevent dispersal of the isotope by returning the power system to earth intact and by providing secondary containment. A launch escape system may be added to separate the power supply from the launch vehicle in the event of an explosion on the pad or of a low level abort. The entire shield and safety equipment subassembly is to be jettisoned once a heliocentric trajectory is established.

The power supply system, including its safety equipment, is installed on the launch vehicle in front of the payload package. The three major subassemblies are: the heat source, the converter equipment which supplies power to the mission, and the safety equipment subassembly which is jettisoned when no longer needed. The mass is 426 kg before and 142 kg

after jettison of the envelope and safety devices.

The radioisotope heat source is a drum-shaped enclosure containing 136 cylindrical capsules of $^{244}\text{Cm}_3\text{O}_2$ in a geometrical array with their axes in parallel alignment. Interspersed with them are the ends of 69 emitter heat pipes that conduct energy to the thermionic cells in the converter subassembly; heat is transferred from the capsules to the pipes by radiation. Another array of 408 auxiliary heat pipes reject heat while the system is on the ground or in the launch phase; this array is part of the safety equipment that is withdrawn from the heat source when the outer envelope is separated.

The thermionic converter subassembly consists of 69 converter cells with their heat pipes, and auxiliary equipment and supporting structures. The two electrical elements of a cell are in the form of concentric cylinders, the inner being the emitter and the outer the collector. The pressure of cesium vapor in the sealed space between the emitter and collector is maintained by a graphite sorption reservoir in the recess in the insulator below the emitter. The emitting surface is formed by vapor deposition of a 0.25-mm (10-mil) layer of tungsten on the end of the emitter heat pipe. Waste heat is removed from the converter by a long heat pipe terminating in a space radiator array.

A beryllium neutron shield protects the payload and power conditioning equipment from radiation while in space, but for added protection, the power supply is pushed away from the payload by extension of a 6-meter boom after the outer envelope has been jettisoned. Stranded aluminum electrical transmission lines conduct the power across the gap.

(continued overleaf)

The safety equipment includes:

1. The 408 auxiliary heat pipes (potassium in stainless steel) which remove heat from the radioisotope capsules prior to and during launch.
2. The helium-filled containment shell which provides secondary containment of the radioisotope and protects refractory metal components from oxidation in the earth's atmosphere.
3. The water container and water circulator to remove isotopic heat prior to launch.
4. The lithium hydride neutron shield to protect persons from neutron radiation prior to launch or following launch aborts.
5. The graphite reentry shield to protect against aerodynamic heating following a high level launch abort.
6. The aerodynamic flare which reduces the ballistic coefficient of the power source and assures a stable reentry attitude.
7. The parachutes which reduce the velocity of impact of the power source on the earth.
8. The impact energy absorber which protects the secondary containment shell and other safety equipment from damage during impact on the earth's surface.
9. A launch escape system which removes the radioisotope heat source from the vicinity of the launch vehicle in the event of a fire or explosion on the launch pad, or a low level launch abort.

The power system has been designed for a mission of 72,000 hours. During the first 18,000 hours and the final 18,000 hours of operation in space, it must

develop full power, but the power requirement is reduced during the intervening 36,000 hours. A mass of 19.5 kg of the isotope, or 21.7 kg of $^{244}\text{Cm}_2\text{O}_3$ must be supplied as a source of 52 kW of thermal power to yield 5 kW of electrical power in this design. Operating temperatures are estimated as 2030°K for the fuel capsules, 1900°K for the emitters, and 1000°K for the space radiators.

Notes:

1. The planned launch vehicle is Titan III-D/Centaur.
2. NASA mission analyses based on characteristics of this design have indicated encouragingly high performance levels for missions to Saturn, Uranus and Neptune.
3. Requests for additional information may be directed to:

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Patent status:

No patent action is contemplated by NASA.

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